Stacks and Queues

CSE 373 - Data Structures

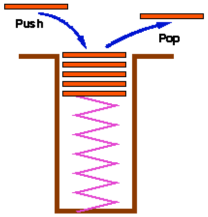
April 12, 2002

Readings and References

- Reading
  - › Section 3.3 and 3.4, *Data Structures and Algorithm Analysis in C*, Weiss
- Other References

Stacks

- A list for which Insert and Delete are allowed only at one end of the list (the *top*)
  - › the implementation defines which end is the "top"
  - › LIFO – Last in, First out
- Push: Insert element at top
- Pop: Remove and return top element (aka TopAndPop)



a tray stack

Stack ADT

```
void push(Stack S, ElementType E)
```

- › **add an entry to the stack for E**

```
ElementType pop(Stack S)
```

- › **remove the top entry from the stack and return it**

```
Stack CreateStack(void)
```

- › **create a new, empty stack**

```
void DestroyStack(Stack S)
```

- › **release all memory associated with this stack**

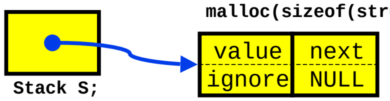
Pointer based Stack implementation

- Linked list with header
- **`typedef struct ListNode *Stack;`**
  - › "Stack" type is a pointer to a List header node
- **`S->next`** points to top of stack, the first node in the List that contains actual data
  - › the data is of type ElementType
- **`push(S,ElementType E);`**
  - › insert a new node at the start of the list

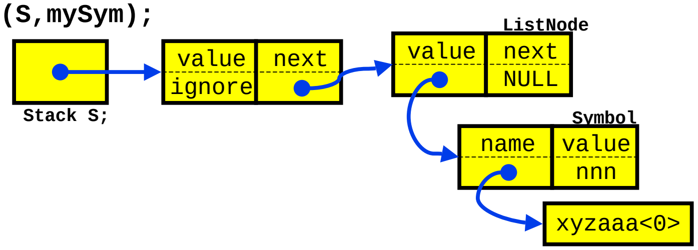
Pointer based stack elements

```
Stack S;
S = CreateStack(100);
```

```
malloc(sizeof(struct ListNode));
```



```
push(S,mySym);
```



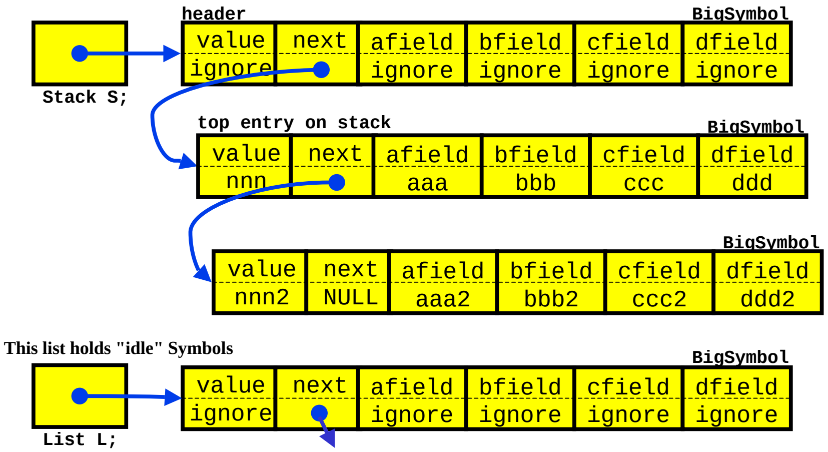
Pointer based Stack issues

- Potentially a lot of calls to malloc and free if the stack is actively used
  - › memory allocation and release require expensive trips through the operating system
- Relatively elaborate data structure for the simple push/pop functions performed
  - › overhead of ListNodes
  - › insert and delete only take place at one end

Pointer based Stack

- Under some circumstances a pointer based stack can be a good choice
- For example, assume
  - › a **`struct Symbol`** is allocated once for each symbol
  - › the symbol is used for a long time in various ways
  - › there is a **`struct Symbol *next`** in each **`struct Symbol`**
  - › then you can use the **`Symbol`** objects as list nodes and link / unlink them with no **`malloc/free`** needed

Stack with BigSymbol nodes



header

BigSymbol

value	next	afield	bfield	cfield	dfield
ignore		ignore	ignore	ignore	ignore

Stack S;

top entry on stack

BigSymbol

value	next	afield	bfield	cfield	dfield
nnn		aaa	bbb	ccc	ddd

BigSymbol

value	next	afield	bfield	cfield	dfield
nnn2	NULL	aaa2	bbb2	ccc2	ddd2

This list holds "idle" Symbols

BigSymbol

value	next	afield	bfield	cfield	dfield
ignore		ignore	ignore	ignore	ignore

List L;

Array based Stack implementation

- Recall the array implementation of Lists
  - › Insert and Delete took O(N) time because we needed to shift elements when operating at an arbitrary position in the list
- What if we avoid shifting by inserting and deleting only at the end of the list?
  - › Both operations take O(1) time!
- Stack: A list for which Insert and Delete are allowed only at one end of the list (the *top*)

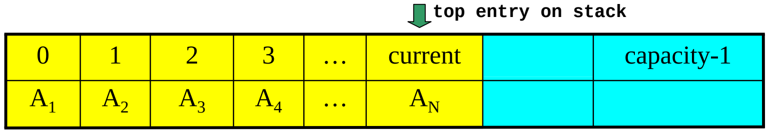
Array based Stack implementation

- An array of ElementType entries
  - › dynamically allocated array
- **`typedef struct StackRecord *Stack;`**
  - › "Stack" type is a pointer to a Stack data record
- **`S->current`** is the array index of the entry at the top of the stack
  - › the data is of type ElementType
- **`push(S,ElementType E);`**
  - › add a new entry at the end (top) of the current list

Array based Stack elements

```
struct StackRecord {
  int capacity;        /* max number of elements */
  int current;         /* offset to most recently pushed value */
  ElementType *buffer; /* pointer to actual stack area */
};

//Empty stack has allocated array and current = -1
```

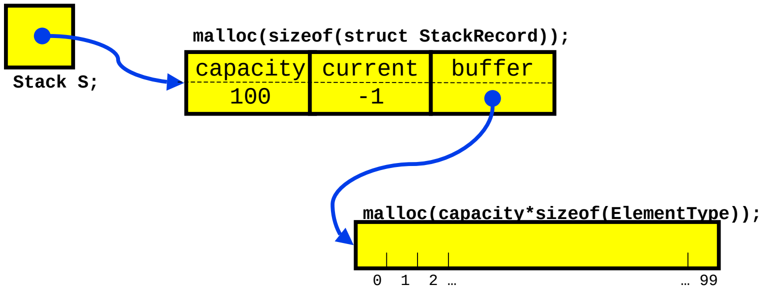


top entry on stack

0	1	2	3	…	current		capacity-1
A_1	A_2	A_3	A_4	…	A_N		

Array based stack create

```
Stack S;
S = CreateStack(100);
```



Stack S;

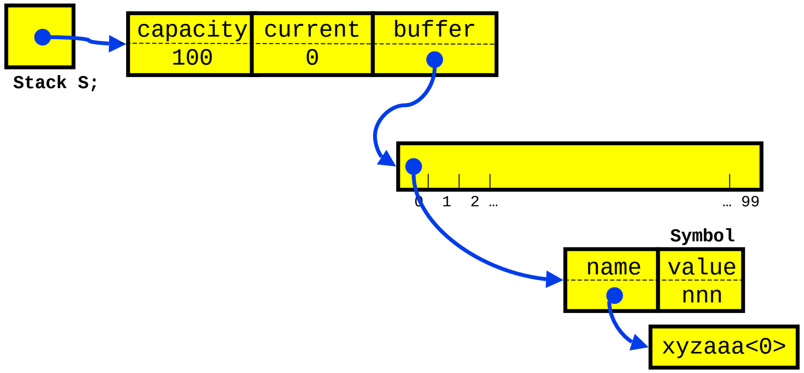
malloc(sizeof(struct StackRecord));

capacity	current	buffer
100	-1	●

malloc(capacity*sizeof(ElementType));

Array based stack push

```
push(S,mySym);
```



Stack S;

capacity	current	buffer
100	0	●

Symbol

name	value
●	nnn

xyzaaa<0>

Array based Stack issues

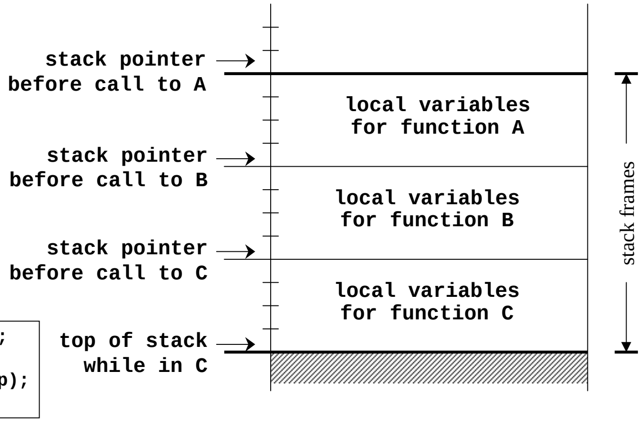
- The array that is used as the Stack must be allocated and may be too big or too small
  - › can dynamically reallocate bigger array on stack overflow
- Error checking
  - › who checks for overflow and underflow?
  - › an array based Stack is so simple that error checking can be a significant percentage cost

(i + 5*(17 – j/(6*k)) : Balanced?

- Balance Checker using Stack
  - › create an empty stack and start reading symbols
  - › If input is an opening symbol, push onto stack
  - › If input is a closing symbol
    - If stack is empty, report error
    - Else, Pop the stack

      Report error if popped symbol is not corresponding open symbol
  - › If EOF and stack is not empty, report error

Using a stack for function calls


stack pointer before call to A
stack pointer before call to B
stack pointer before call to C
top of stack while in C
local variables for function A
local variables for function B
local variables for function C
stack frames

```
main: myVar = A(x);
in A: k = B(x,2);
in B: z = C(500,tmp);
in C: myVal = a+b;
```

Using a Stack for Arithmetic

- infix notation : a+b*c+(d*e+f)*g
  - › the operators are between the operands
- postfix notation: abc*+de*f+g*+
  - › the operators follow the operands
- convert to postfix using a stack
  - › read the input stream of characters
  - › output operands as they are seen
  - › push and pop operators according to priority
- evaluate postfix expression using a stack

Queue

- Insert at one end of List, remove at the other end
- Queues are “FIFO” – first in, first out
- Primary operations are Enqueue and Dequeue
- A queue ensures “fairness”
  - › customers waiting on a customer hotline
  - › processes waiting to run on the CPU

Queue ADT

- Operations:
  - › void Enqueue(Queue Q, ElementType E)
    - add an entry at the end of the queue
  - › ElementType Dequeue(Queue Q)
    - remove the entry from the beginning of the queue
    - aka ElementType FrontAndDequeue(Queue Q)
  - › int IsEmpty(Queue Q)

Queue ADT

- Pointer-based: what pointers do you need to keep track of for O(1) implementation?
- Array-based: can use List operations Insert and Delete, but O(N) time due to copying
- How can you make array-based Enqueue and Dequeue O(1) time?
  - Use Front and Rear indices: Rear incremented for Enqueue and Front incremented for Dequeue

Applications of Queues

- File servers: Users needing access to their files on a shared file server machine are given access on a FIFO basis
- Printer Queue: Jobs submitted to a printer are printed in order of arrival
- Phone calls made to customer service hotlines are usually placed in a queue